BELLCOMM, INC.

SUBJECT: Unmanned Entry Probe Sizing for a 1975 Manned Mars Flyby Mission Case 103-2

DATE: July 11, 1966

FROM: D. E. Cassidy

ABSTRACT

Generalized growth factors have been established for unmanned probes entering the Martian atmosphere. Both soft landing and atmospheric sampling probes are practical within reasonable size and weight constraints. Minimum gross weights exist for the soft landers by trading off entry shell structural weight for terminal propulsion. This is shown to yield a diameter of 12 feet for a 1400 pound payload.

Large gross weight penalties could result from pre-entry targeting requirements but these need not affect the entry shell diameter or weight when a separate pre-entry propulsion system is used.

Specific probes have been sized to soft land a 1400 pound and a 350 pound payload, and to deliver a 45 pound payload for atmospheric sampling.

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MEMORANDUM FOR FILE

Introduction

The data presented here represents best estimates of weights and sizes of entry probes required to obtain Mars atmospheric and surface data, including the delivery of an Automated Biological Laboratory, television, geophysical sensing instruments, and possible soil sample retriever. Full advantage is taken of the manned spacecraft to establish narrow entry corridors on the order of 10 to 20 nautical miles, thus permitting shallow entry angles.

The probes will be divided into two categories. The atmospheric probes, which telemeter data before impact and do not require surviving surface impact, and soft landers which will utilize terminal propulsive retardation to a nominal zero rate of sink.

MISSION MODES

The pre-entry sequence for all probes will be considered similar. The probe separates from the spacecraft and the protective sterilization container is jettisoned. Depending on the targeting requirements, which could be different for each probe, a one or two stage propulsion system will inject the probe into a 10 to 20 nautical mile entry corridor in advance of the spacecraft. The propulsive ΔV required for targeting is a study parameter and will vary with injection distance and spacecraft periapsis passage altitude. The nominal value is 400 fps and is varied to 5000 fps.

The nominal entry trajectory is along the undershoot boundary of the 20 N.M. corridor. This represents the worst case within the corridor in terms of data transmission time after communications black-out for the atmospheric probes, and landing propulsion for the soft landers.

At some time prior to entry, the entry configuration is separated from all pre-entry systems, i.e., targeting propulsion guidance, altitude control, etc., not required for the entry and post entry phases. This is required to reduce the entry weight to provide a minimum ballistic parameter. Figure (1) shows the 60° conical entry shell configuration with a possible pre-entry systems bay attached to the conical base.

Following entry, the entry shell follows a ballistic, i.e., non-lifting and unguided, path through the Martian VM-8[1] model atmosphere. The nominal probe entry velocity is 30,000 fps at 120 N.M. which will be effected by the pre-entry targeting requirements, but not sufficiently to appreciably effect the vehicle sizing. All vehicles were sized to an ultimate load factor of 100 earth "g's". While this is a factor of 2 high for the undershoot trajectory, it represents a conservative shell structural penalty which is most severe at the higher ballistic parameters for a given diameter. The reason for this is that the lower ballistic parameter shell structures tend to be minimum gage limited and therefore less sensitive to aerodynamic loading.

SOFT LANDER SIZING

PAYLOAD WEIGHT

The useful payload delivered to the Martian surface is presented in Figure (2) as a function of entry shell diameter and ballistic parameter, where packaging density is included as a constraining parameter. It is noted that diameter reduction can be achieved with increased ballistic parameters (m/C_DA) to about.8. At higher m/C_DA the ability to package within the entry shell becomes increasingly more difficult.

The useful payload includes all experiments, power systems, telemetry systems, etc., but does not include the payload structure and ground leveling supports. It was estimated that 40% of the useful payload would account for the payload structure and supports. In addition, a 20% contingency was included as a growth factor resulting in the useful payload representing 60% of the landed weight.

The terminal propulsion system utilizes storable liquid propellants with an Isp of 300 and a propellant loading of .85. Prior to terminal rocket firing, which occurs at about 10,000 feet altitude, the structural entry shell is jettisoned to minimize landing weight and fuel consumption. The dynamic pressure at this point is less than .04 earth atmospheres for the $m/C_DA = 1$ and less than .01 for the $m/C_DA = .6$ and should not penalize propulsion system performance.

GROSS WEIGHT

Summing up all component weights results in the gross weight on board the spacecraft presented in Figure (3). The gross weights include the following major systems weights:

1) Sterilization container
2) Injection propulsion system (400 fps ΔV)
3) Entry shell structure plus heat shield
4) Terminal Propulsion
5) Useful payload
6) Payload structure

The shell structure plus heat shield weights are presented separately in Figure (4).

It is noted from Figure (5) that a minimum gross weight for a given payload weight exists. This is due to the larger terminal propulsion system weight required as the diameter is reduced. For large diameters the shell structure and heat shield have large mass fractions and approach a minimum at the small diameters.

PACKAGING

It must be noted that the density parameter of Figure (2) only applies to packaging within the conical entry shell. If packaging is extended beyond the base, as suggested by the dashed lines on Figure (1), the "effective" density will be reduced proportionally to the increased packaging volume. Since the center of pressure of the shell is over a body length aft of the base, packaging can be extended behind the base[2] still insuring the center of gravity is forward of the center of pressure for static stability.

TARGETING REQUIREMENTS

The requirement to disperse the payloads on the Martian surface or provide additional lead time between payload landing and spacecraft periapsis passage results in the gross weight penalties presented in Figures (6), (7), and (8) for m/C_DA of .4, .6 and .8 respectively. The injection propulsion system has an Isp of 250 and a propellant loading of .9.

ATMOSPHERIC PROBES/HARD LANDER

The differences between the atmospheric probes and soft landers are the elimination of any terminal retardation and ground leveling supports and reduced payload structural weight. The payload structural fraction is taken to be 20% of the payload with a 20% contingency factor.

Figure (9) presents the useful payload delivered for sampling the atmosphere and transmitting data. Higher densities are indicated since the atmospheric probes will contain less low density items. The gross weights required in the spacecraft to deliver the required payloads are presented in Figure (10).

As in the case of the soft landers, targeting constraints increase the gross weight. This is illustrated in Figure (11) for the $m/C_DA = .2$. The $.2\ m/C_DA$ vehicle is considered here since it provides over two minutes of transmission time after communications black-out. Black-out is assumed to end at a velocity of 10,000 fps. Two minutes is probably more than is required so an m/C_DA of .25 or .3 might be possible upon closer analysis.

SPECIFIC PAYLOADS

Three vehicles are sized here to provide for three specific payloads. Based on the scaling data presented previously, the payloads, entry shell diameters, and gross weights (400 fps ΔV) on board the spacecraft are:

SOFT LANDERS

PAYLOAD (LBS)	DIAMETER (FEET)	GROSS WEIGHT (LBS)
1400	12	3800
350	8-1/2	1000

ATMOSPHERIC PROBE

PAYLOAD (LBS)	DIAMETER (FEET)	GROSS WEIGHT (LBS)
45	3 1/2	110

CONCLUSION

Generalized growth factors have been established for unmanned probes entering the Martian atmosphere. Both soft landing and atmospheric sampling probes are practical within reasonable size and weight constraints. Minimum gross weights exist for the soft landers by trading off entry shell structural weight for terminal propulsion. This is shown to yield a diameter of 12 feet for a 1400 pound payload.

Large gross weight penalties could result from pre-entry targeting requirements but need not affect the entry shell diameter or weight when utilizing a separate pre-entry systems bay.

Specific probes have been sized to soft land a 1400 pound and a 350 pound payload, and to deliver 45 pound payload for atmospheric sampling.

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1021-DEC-wlm D. E. Cassidy

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2. Aerodynamic Characteristics of Blunt Bodies, JPL Technical Report No. 32-677, Nov. 19, 1964.

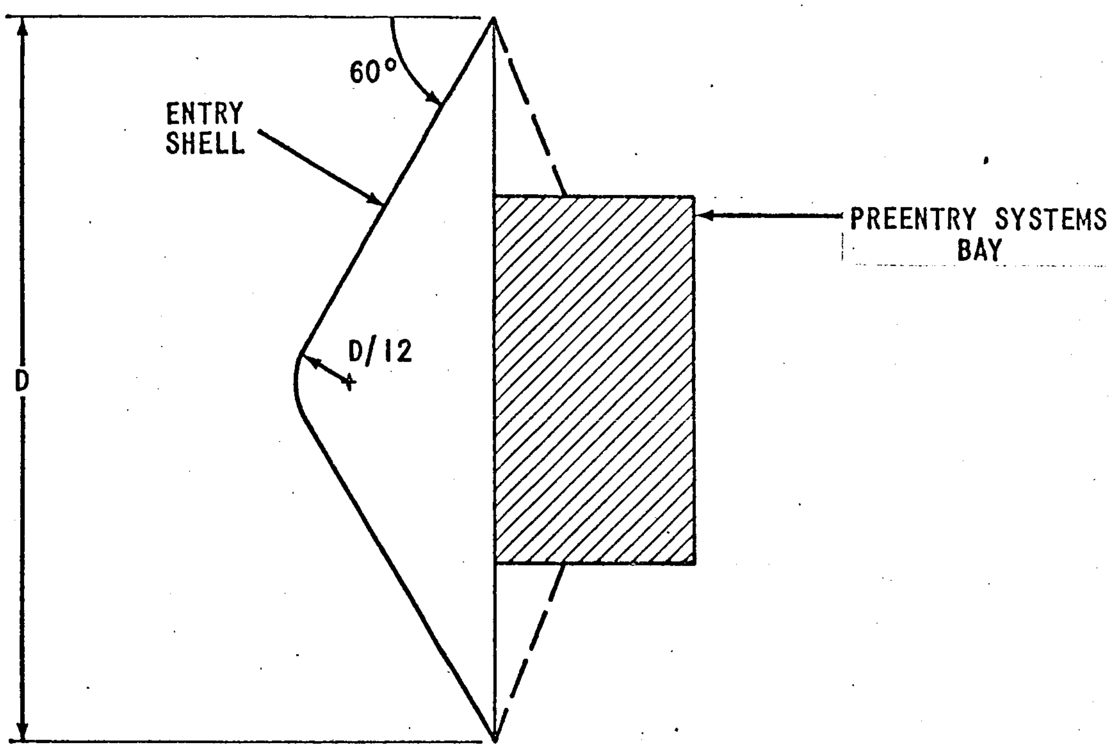

FIGURE 1 - UNMANNED PROBE CONFIGURATION

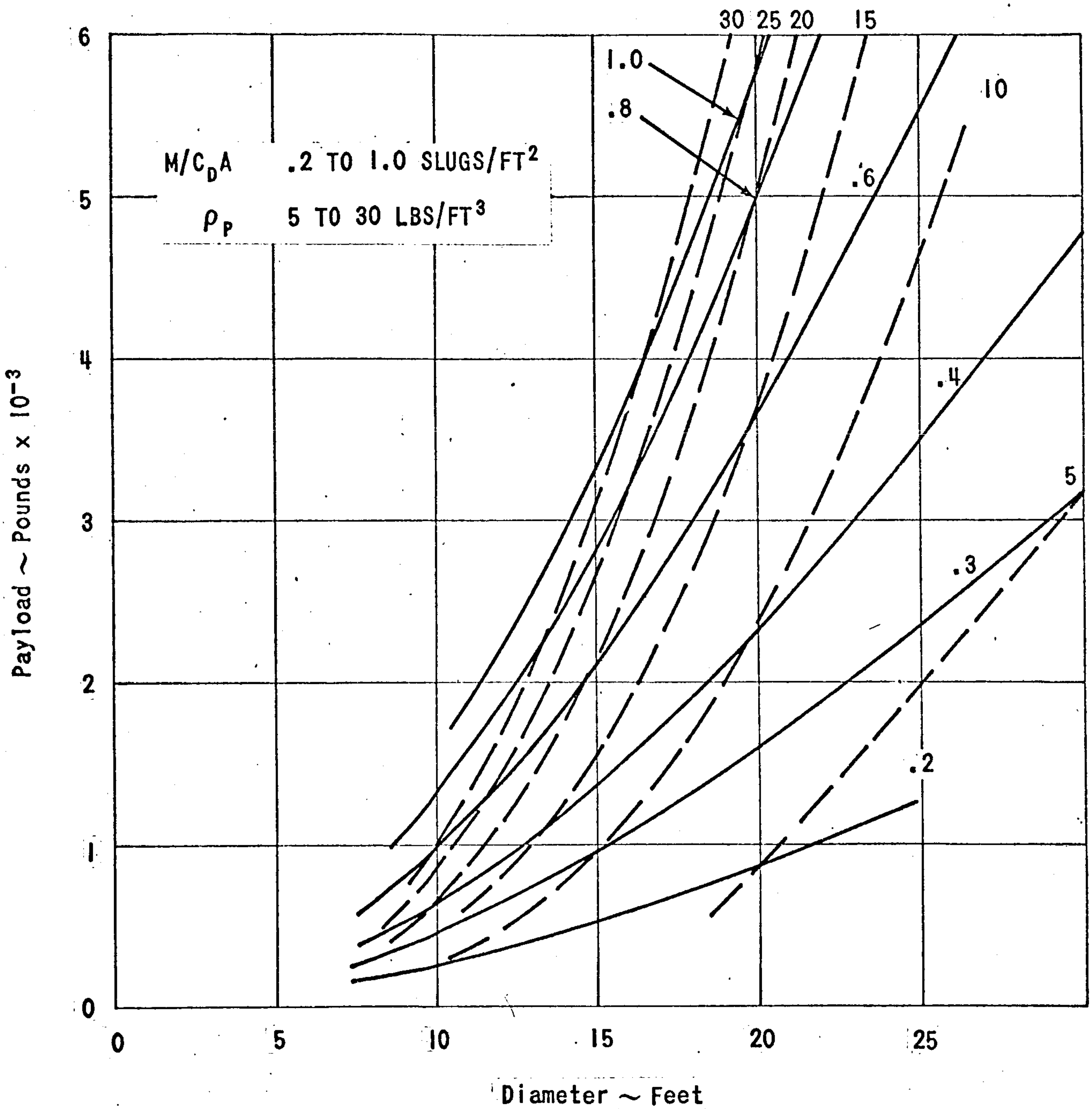

FIGURE 2 - PAYLOAD - DIAMETER FOR SOFT LANDER

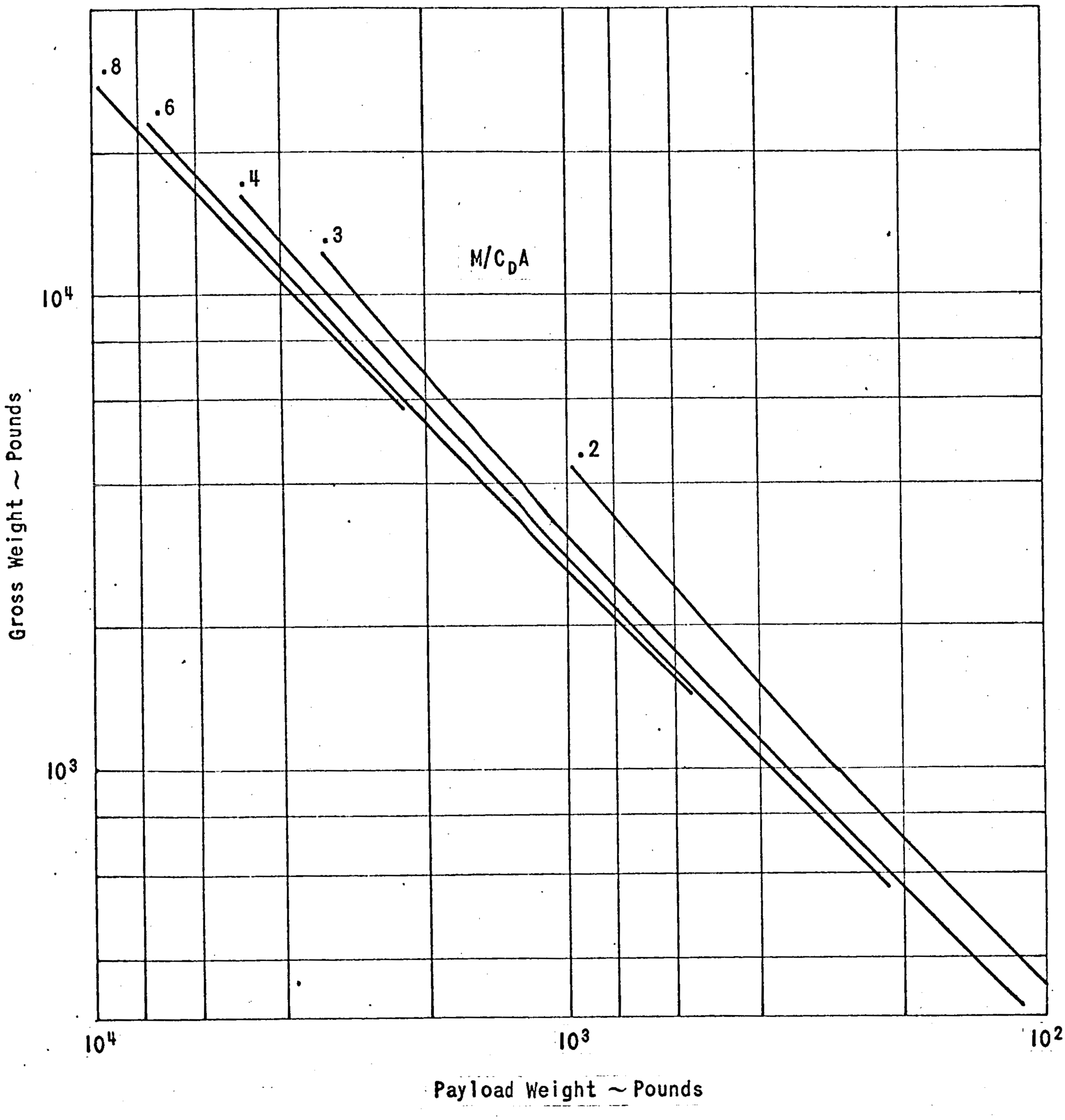

FIGURE 3 - GROSS WEIGHT - PAYLOAD FOR SOFT LANDER

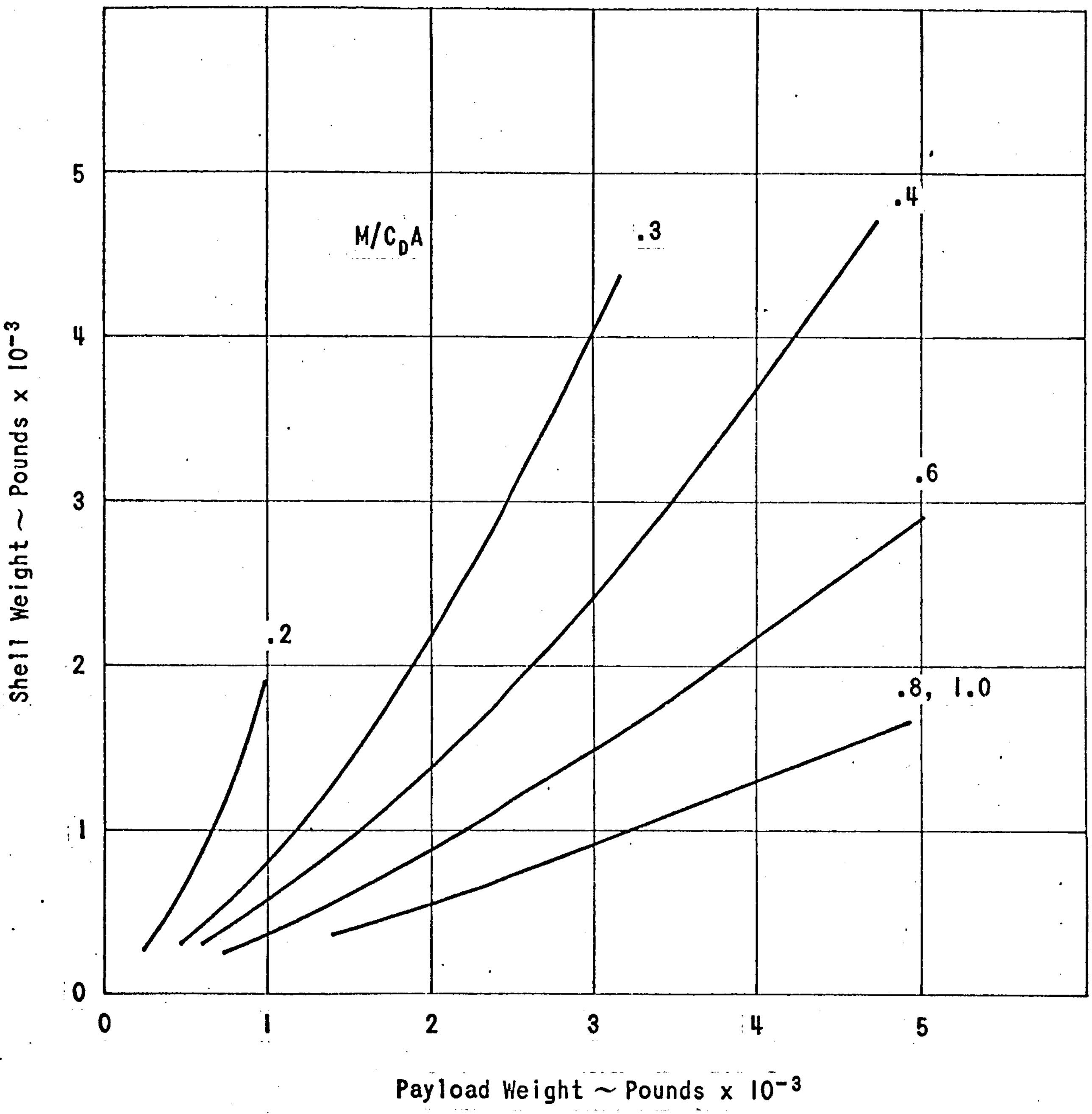

FIGURE 4 - ENTRY SHELL STRUCTURAL PLUS HEAT SHIELD WEIGHT

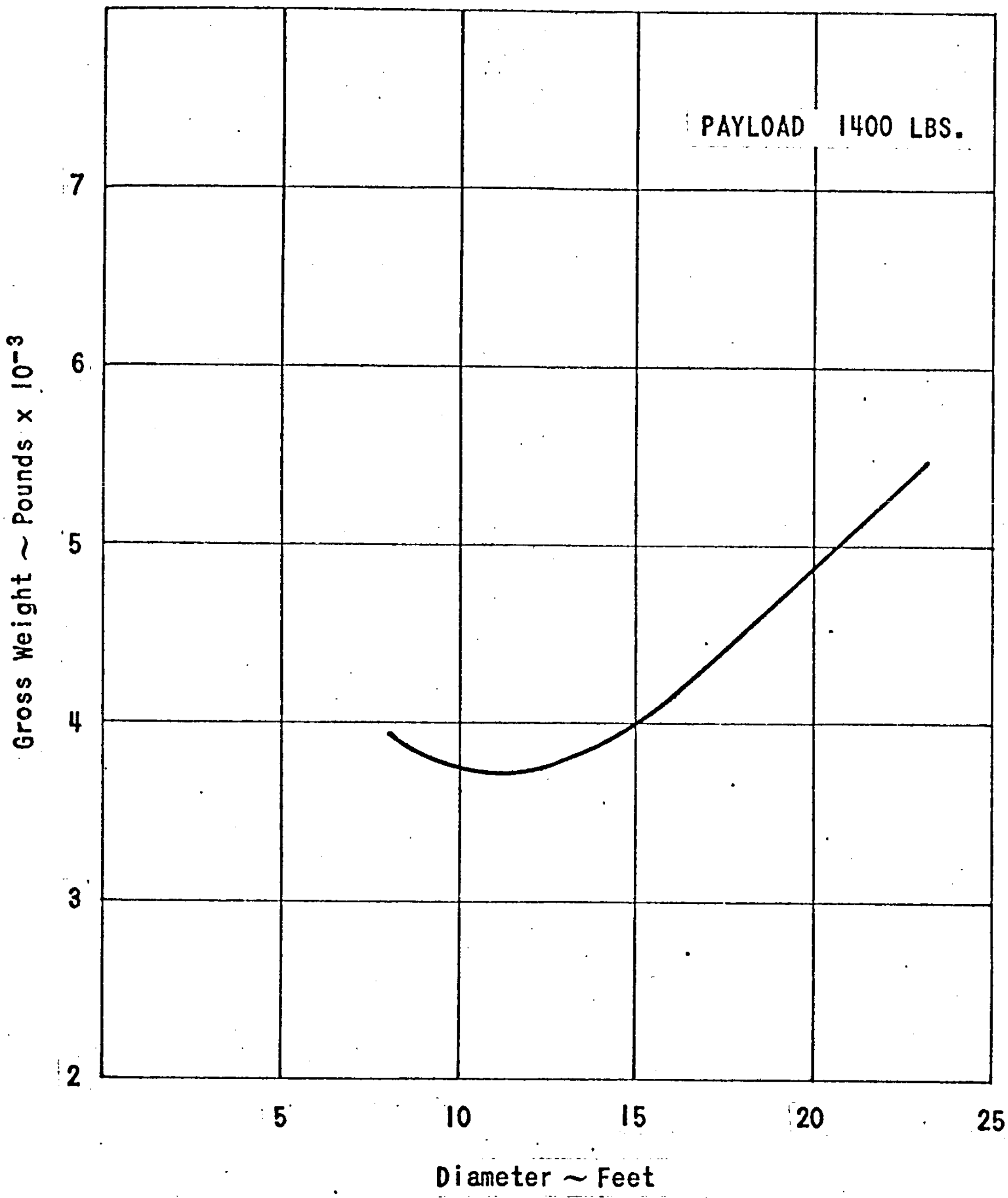

FIGURE 5 - GROSS WEIGHT - DIAMETER SOFT LANDER

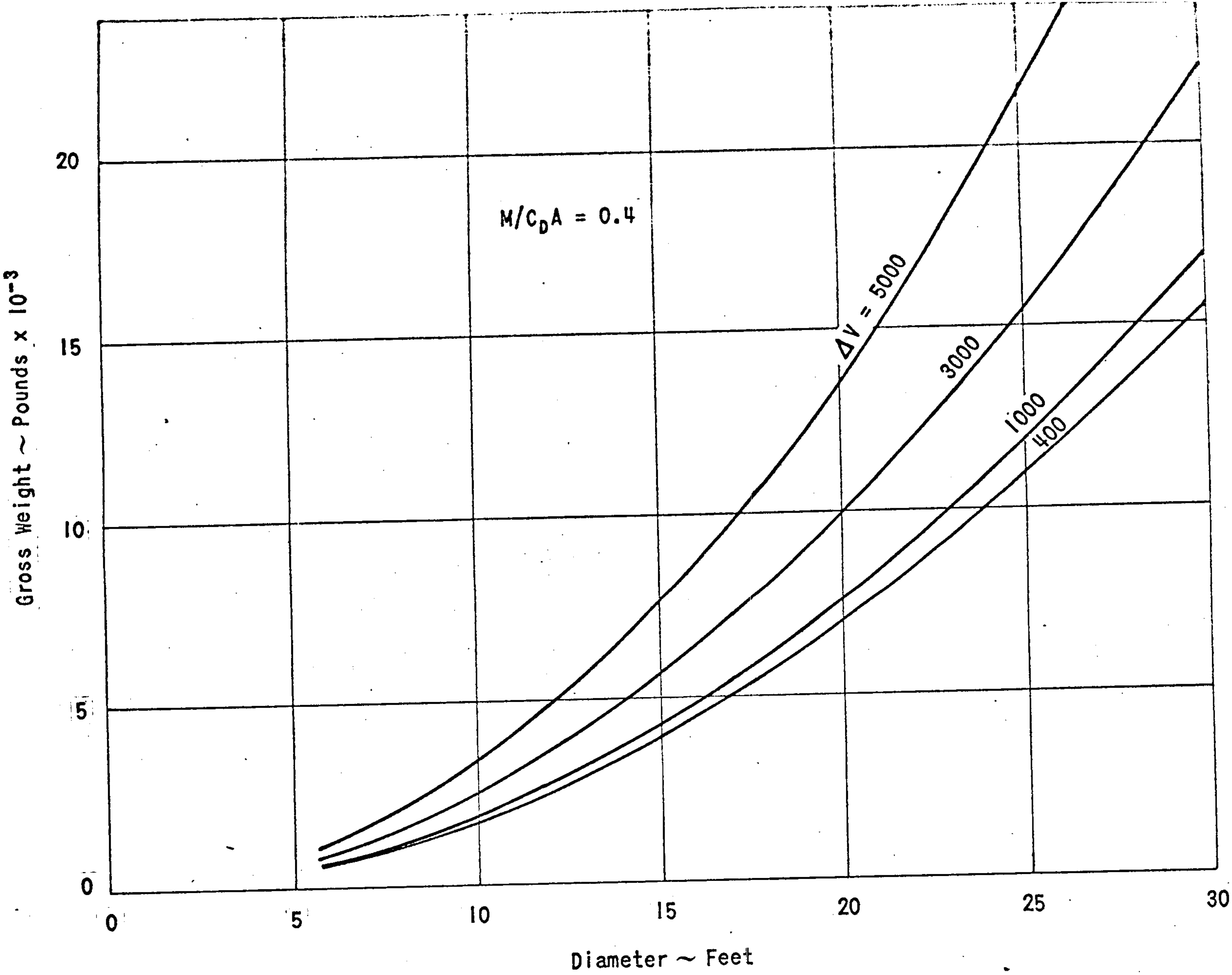

FIGURE 6 - GROSS WEIGHT TARGETING PENALTY

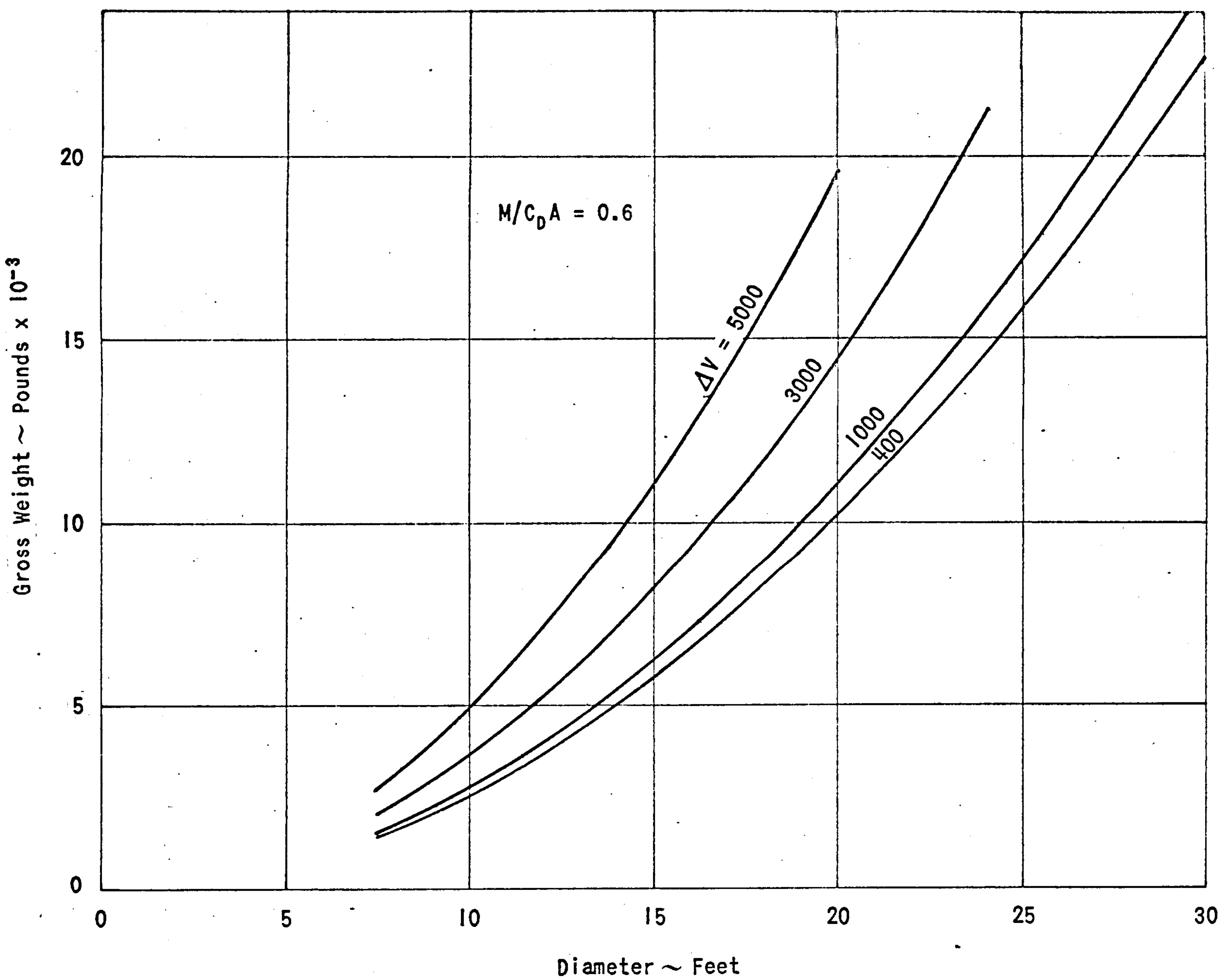

FIGURE 7 - GROSS WEIGHT TARGETING PENALTY

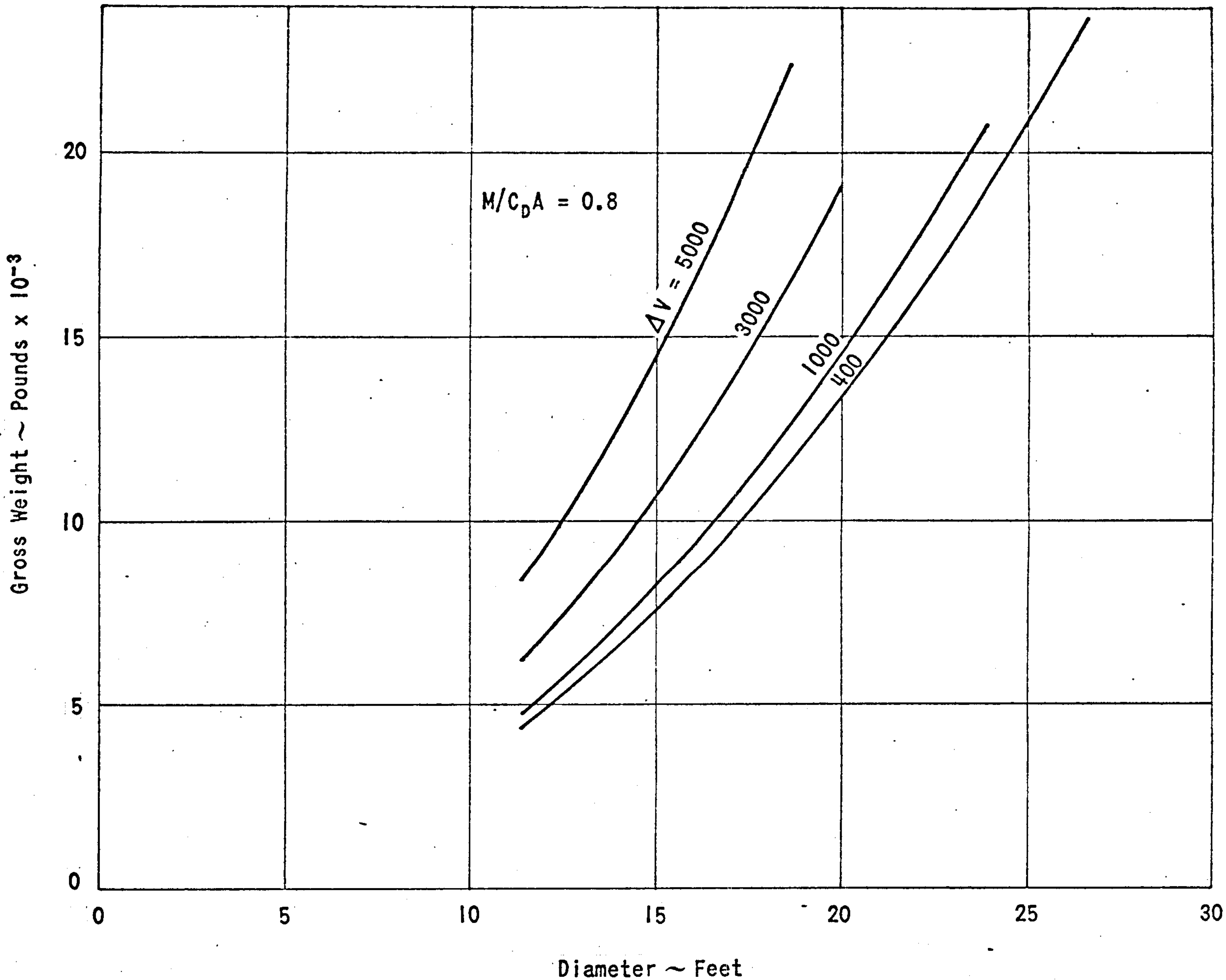

FIGURE 8 - GROSS WEIGHT TARGETING PENALTY

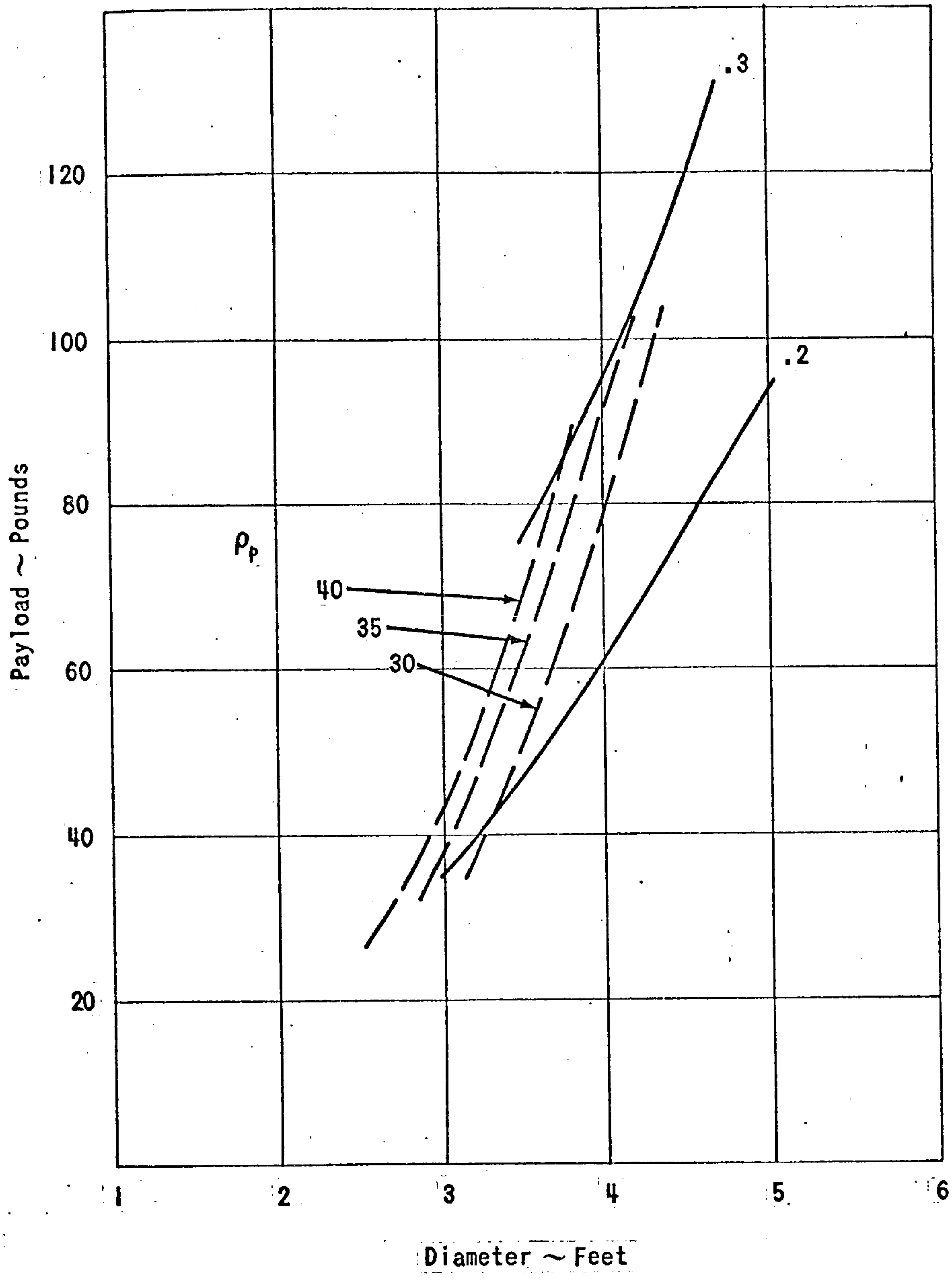

FIGURE 9 - PAYLOAD - DIAMETER ATMOSPHERIC PROBE/HARD LANDER

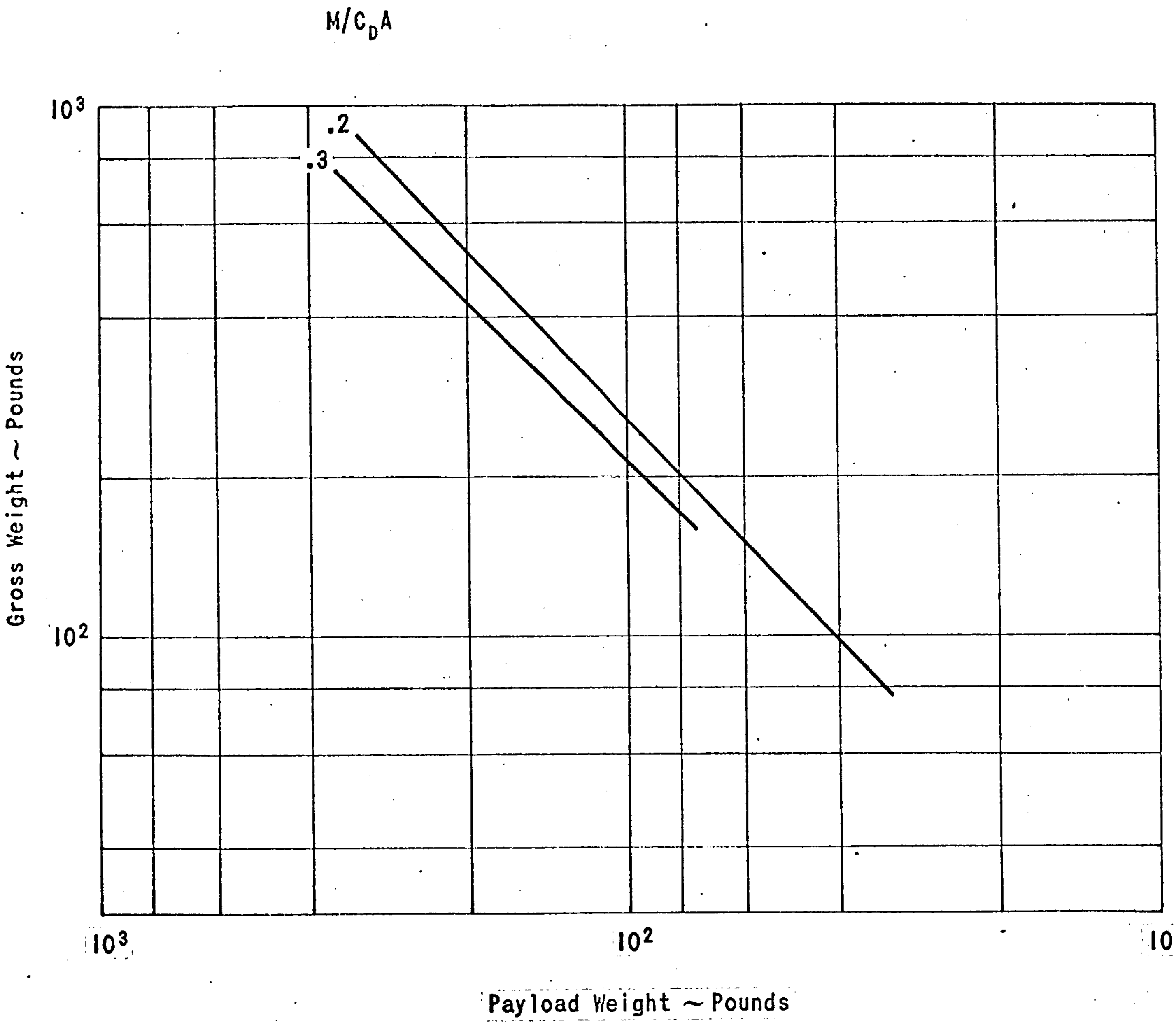

FIGURE 10 - GROSS WEIGHT - PAYLOAD ATMOSPHERIC PROBES/HARD LANDERS

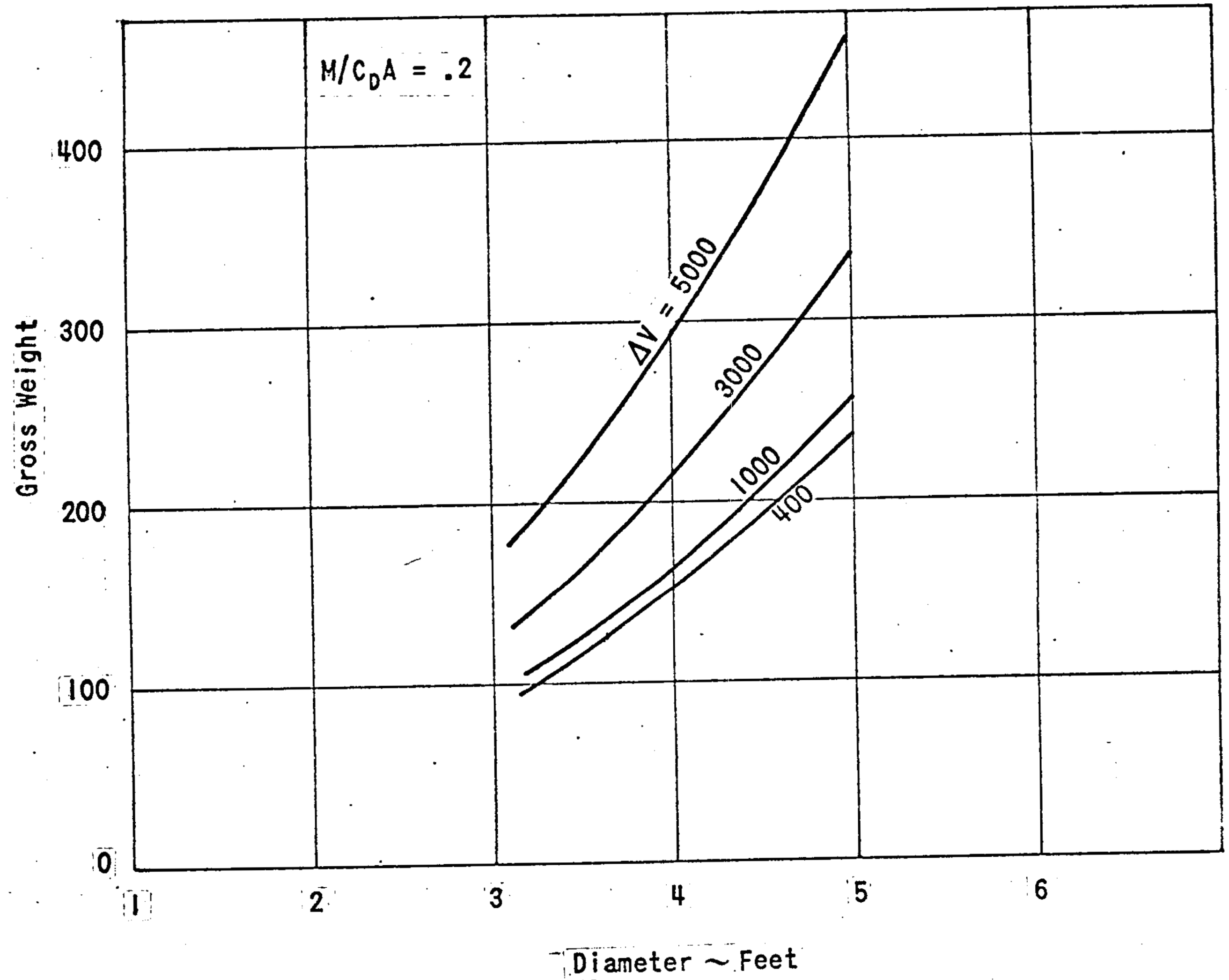

FIGURE II - GROSS WEIGHT TARGETING PENALTY